PRELIMINARY RESULTS OF A RECREATIONAL USE ATTAINABILITY ANALYSIS OF THE BUFFALO BAYOU/WHITE OAK BAYOU STREAM SYSTEM IN HOUSTON, TEXAS

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INTRODUCTION

Recreational Use Attainability Analyses (RUAA) are scientific assessments carried out on streams to determine whether the existing and/or attainable recreational use for a particular classified or unclassified water body might be different than the presumed recreational use as specified in the Clean Water Act. RUAAs generally include physical, chemical, and biological evaluations to determine what factors impair attainment of designated uses and provide information to determine what uses are appropriate and feasible for the water body in question. Important factors in such analyses include naturally occurring pollutant concentrations, anthropogenic sources of pollution, water depth, hydrological modifications, and natural physical characteristics of streams that could impair use. In addition, RUAAs typically assess the current uses (recreation and otherwise) of the water bodies under evaluation.

In 2006, streams in Houston, Texas, including unclassified water bodies that were presumed to have contact recreation uses as described in 307.4(j) in the Texas Surface Water Quality Standards (TSWQS), were found to be impaired and placed on the Environmental Protection Agencies 303(d) List. At a recent Buffalo Bayou/White Oak Bayou TMDL process meeting, local Houston area stakeholders expressed concerns as to whether or not the current recreational WQS uses and associated criteria for certain Houston water bodies are appropriate.

On June 6, 2008, a RUAA began on the Buffalo Bayou/White Oak Bayou Stream system to determine what designated or beneficial uses and criteria described in the TSWQS may be attainable. This RUAA will help assess the physical, chemical, biological, geographic, and infrastructure factors that influence recreational use attainment of this water body. The RUAA will provide the Texas Commission on Environmental Quality Water (TCEQ) Quality Standards Team with relevant information to determine if the current classification of the Houston streams in question is appropriate.

HISTORIC INFORMATION

Buffalo Bayou has been the commercial hub of Houston since the founding of the city in 1836. In the early history of Houston, the city was planned primarily in accordance with the orientation of the Bayou to fully capture its shipping capacity and economic opportunities. All the freight was gathered to load or unload commercial goods at Allen's Landing, which was located at the foot of present day Main and Commerce Streets (BBP, 2008). Commercial and transportation activities around the Bayou also drove real estate and industrial (e.g., lumber, railroads, and brewery) development along the Bayou bank (Foshée, 2006). Several historical accounts have indicated that various recreational activities were pursued by different Houston communities on or around the Bayou in the 1800s (Aulbach, 2004; Johnston, 1991; Fuller, 1987). The early parks by the Bayou (e.g., Magnolia Park, Vick's Park, Sam Houston Park, San Jacinto Park and private clubs or resorts (e.g., Beachamp Springs, The Bayou Club) were places where Houstonians enjoyed festivals, picnics, boating, canoeing, swimming, fishing, dancing, and social gatherings. In the late 1800s, Buffalo Bayou was a popular place for recreation and swimming. The recreational activities and settings are summarized as follows

Festivals

i. Volksfest: primarily celebrated by the German communities and taken place at Volksfest Park on Buffalo Bayou in each May until the turn of the 20th century. Events of the festival included a parade, folk dancing, ice cream, baseball games, speeches, and gymnastics competitions
ii. The No-Tsu-O Festival: lasted for one week to celebrate the success of the markets in each November between 1899 and 1915 (Johnston, 1991). The festival symbolized Houstonians' economic dependence on the Bayou for that it provided the waterway to transport cotton, the primarily economic crop of the time, throughout the country and to the international market. Lots activities of the festival occurred on the Bayou.
iii. The Texas State Fair: The state fair was held on the north bank of Buffalo Bayou. The festival was originated in 1870 and ended in 1878 due to the economic depression.

b. *Boating*

Figure 1. Boating scene (circa 1900)

Cruising was popular among Houstonians to transport them to parks, such as Magnolia Park, San Jacinto Park, and Zero Ice Factory grounds, and festivals until cars and trains became more prevalent (Figure 1). The Buffalo Bayou cruises were also popular for wedding parties, fine dining, and dancing (Henson, Glass, & Moore, 1991). Houstonians have also been using Buffalo Bayou for water recreation of yachting, canoeing, kayaking, and dragon boating. The oldest yacht club in Texas, the Houston Yacht Club, was formed in 1897 to promote the science and sport of boating, and maintaining a cleaner and healthier bayou (HYC 2008). Members of the club moored their boats near Allen's Landings until the club house was moved to Port of Houston in 1910 and Galveston Bay after World War I. HYC continues to promote yacht racing and recreational boating nowadays. The Houston Canoe Club was established in 1964 (Houston Canoe Club, 2008). Members of the club have been participating in paddle sport such as canoeing and kayaking in the Houston area including Buffalo Bayou. Texas Dragon Boat Association was established in 2003 to promote dragon boating and to increase awareness of Asian and Asian-American culture and cross-cultural understanding (Texas Dragon Boat Association, 2008). The association organized the first Houston Dragon Boat Festival in the same year when it was established. The festival continues in each May on Buffalo Bayou since then.

Figure 2. Swimming (circa 1935)

c. *Swimming*

Swimming was common on Buffalo Bayou in the 1800s and early 1900s

(Figure 2). Vick's Park, Arsenal Swimming Hole, the Russia Swimming Hole, and swimming holes located close to the present Waugh Drive and Shepherd Drive (Figure 3) as well as Memorial Park were popular recreation sites (Aulbach, 2004). Segments of Buffalo Bayou (Segment 1014) and White Oak Bayou (Segment 1017) are listed as nonsupport for the contact recreation use such as swimming since 1996 due to the higher than the recommended criterion for fecal coliform bacteria (TCEQ, 1996).

Figure 3. Shepherd's Dam (circa 1907)

d. Picnicking and social gatherings

Vick's Park, Dolly Varden Point, old fairgrounds at McGowan and Milam, Merkel's Grove, Volksfest Park, San Jacinto Park, Magnolia Park were places along Buffalo Bayou where Houstonians visited for picnics and social gathering in the past.

e. Fishing

Houstonians fished at where Memorial Park and Shepherd's Dam are now located (Figure 4). Now fishing can be found at Addicks and Barker reservoirs, Allens Landing Park, and along the East End trails (Foshée, 2006, U.S. Army Corps of Engineers, 2008).

Figure 4. Fishing (year unknown)

f. Birding

Since 1978, the Buffalo Bayou Christmas Count (CBC) has been held along or near the Bayou. The purpose of the event is to document the birds on the west of the city where rapid development has been changing the habitat of

many bird species (Houston Arboretum & Nature Center, 2008). One hundred and twenty-three bird species, with a total of 32,599 bird counts, were reported during the 2006 CBC.

g. Parks/private clubs and resorts

a. Magnolia Park was built in the 1880s at one of the largest Mexican-American neighborhoods in Houston. It was used as a place for Mexican-American cultural celebrations (e.g., Fiestas Patrias). The park occupies a portion of Hidalgo Park and remains popular for Mexican cultural celebrations and social gatherings.
b. Memorial Park used to be a military training base during World War I (Camp Logan), and became a city park in 1925 to honor the memory of the soldiers who had trained there. The design of the park was to facilitate recreational activities such as golfing, scenic driving, and hiking as well as for wildlife habitat (Memorial Park Conservancy, 2008).
c. Beauchamp Springs was located on White Oak Bayou near Woodland Park. The springs were a major source of drinking water for residents of Houston in the early years of the city's history and a popular resort in the mid-1800s (The Handbook of Texas Online, 2008). Promenade grounds, manicured forests, and festival events were some of the features found in the resort (Foshée, 2006). The flow of the springs was greatly reduced after a nearby highway was developed in the 1980s (The Handbook of Texas Online, 2008).
d. Vick's Lake Park was located on the north bank of Buffalo Bayou between the present Studemont Street and Waugh Drive. The park was one of the best areas in Houston for picnicking and swimming (Aulbach, 2005). A segment of it is now part of Spotts Park (Foshée, 2006).
e. Sam Houston Park was located across Buffalo Bayou's banks and included the Samuel Young brick yard on the north and the Kellum-Noble Home and Sarah Bryers Nursery on the South (Foshée, 2006). It was established in 1900 as the first city park of Houston that was

designed as a Victorian landscape with an old mill, a stream, a rustic bridge, and paths (The Heritage Society at Sam Houston Park, 2008).

f. Sesquicentennial Park was once a site of a private home and ranch (Foshée, 2006). The park was established in 1986 to celebrate the 150-year founding anniversary of Houston and Texas in 1986. The park design was oriented to address multiple objectives, such as developing an urban space that brings people to Buffalo Bayou, manifesting ecological aspects, helping to satisfy public demand for outdoor recreation while maintaining the drainage functions of Buffalo Bayou, and providing an accessible open space for all citizens (Fuller, 1988).
g. Volksfest Park was where the German Volksfest was held and used for Sunday picnics (Moss, 1997).
h. The Bayou Club was a private country club established in 1938 and is still providing its membership with tennis, polo, and swimming (Johnson, 1991).

Locations of the parks are shown on Figure 5. In addition to water-based recreational activities, Buffalo Bayou also provided water sources for industrial uses, public fountains, and fire hydrants (Johnston, 1991). However, increased traffic on the waterway, industrial activities, and sewage discharged from residential areas contributed to the deterioration of the Bayou's water quality. Concern about pollution of the Bayou can be traced back to 1841 when sawmills were the major source of pollution (Aulbach, 2004). In the early 1970s, water pollution became the focus of attention, and the city of Houston was identified as the major source partly due to inadequate and overloaded sewage treatment plants (Miller, 1992). Unrestricted development and pollution along with occasionally severe flooding had impaired Houstonians' perception of Buffalo Bayou and the quality of recreation that it supported (Fuller, 1987).

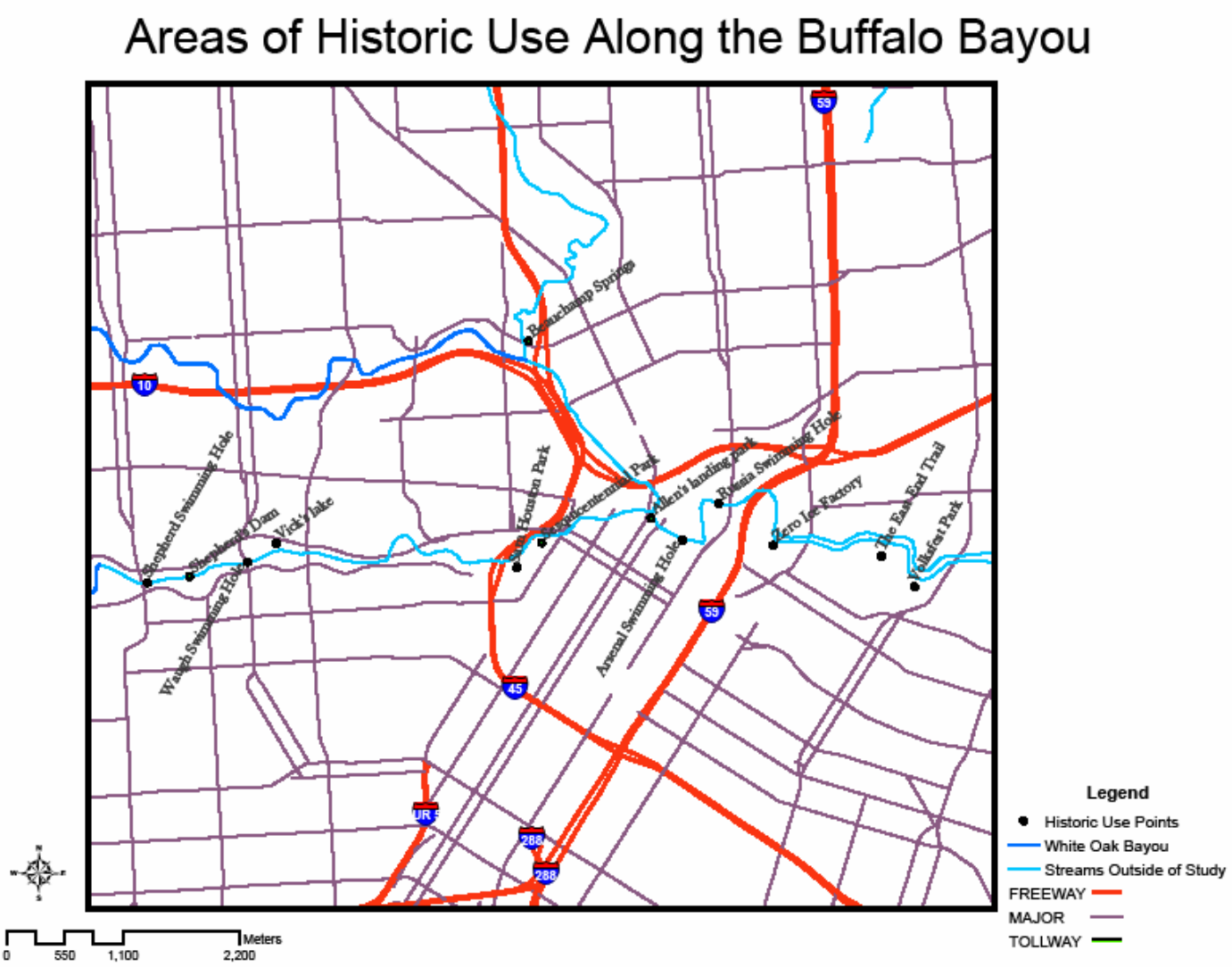

Figure 5. Areas of Historic use along Buffalo Bayou.

DESCRIPTION OF THE STUDY AREA

The Buffalo Bayou/White Oak Bayou Stream System consists of approximately of 151 miles of streams located in the San Jacinto River Basin, primarily in Harris County, Texas. These streams, which consist of natural, channelized and concrete-lined segments, provide Houston area residents with a conduit for the runoff of storm water, municipal wastewater, and industrial effluent, natural areas for recreation, and waterways for recreational and commercial (generally below the confluence of Buffalo Bayou and White Oak Bayou) navigation. Buffalo Bayou and White Oak Bayou are the two largest streams in this system. They connect in downtown Houston before flowing into Galveston Bay. Buffalo Bayou and its tributaries, which include Buffalo Bayou Classified (BBC), Buffalo Bayou Unclassified (BBU), Bear Creek (BC), Langham Creek (LC), Mason Creek (MC), Newmans Branch (NB), Rummel Creek (RC), Spring Branch (SB), South Mayde Creek (SMC), and Turkey Creek (TC) (Figure 8) (Table 1), flow predominately through suburban/residential areas with portions that also flow through natural, agricultural, pastoral, commercial and industrial areas. White Oak Bayou and its tributaries, which include White Oak Bayou (WOB), Brickhouse Gully (BG), Cole Creek (CC), a Canal at Magnum Road and US 290 (MAG), and an unnamed tributary of White Oak Bayou near Beall Street (UNK), also primarily flow through suburban/residential areas (Figure 9). These streams, in contrast to Buffalo Bayou and its tributaries, are physically more altered and have proportionately more segments that are located in commercial and industrial areas.

METHODS

Creation of GIS Project

An ESRI ArcMap GIS project was created to identify the boundaries of the streams included in the RUAA and acquire the information needed to carry out the RUAA. ArcMap stream coverages were obtained from TCEQs Atlas of Texas Surface Waters (b10_rev-streams). Shapefiles of Texas counties (counties.shp), Harris county cities (cities98.shp), and stream point sources (tx_wastewtr outfall) were also obtained from TCEQ. A watershed coverage (basinspy) was obtained from Texas Parks and Wildlife. Shapefiles for highways (HIGHWAY LABELS), major roads (major roads), county parks (County Parks), county trails (County_trails), and wetlands (harris-nwi_sp83) were obtained from Harris County Public Infrastructure Department Architecture and Engineering Division. Aerial photographs (2004 NAIP 1m) and street shapefiles (x201_v2.shp, x157_v2.shp, and x473_v2.shp) were obtained from the Texas Natural Resources Information System.

Sampling Design and Site Selection

A systematic sampling method was used to select survey stations within the stream networks. Using the b10_rev-streams coverage for each stream, survey stations were spaced evenly every 1.67 miles or 3 points per 5 mile segment of stream. This methodology ensured that the survey stations provided a representative sample of the conditions that exist along the entire population of streams. Two survey events were conducted at each station between June 6 and August 10, 2008. Environmental, recreational use, and human presence sampling occurred at 85 survey stations along 151 miles of streams in the Buffalo Bayou/White Oak Bayou Stream System.

Environmental Assessment Methodology

Quantitative measurements and categorical observations of various environmental stream attributes (Appendix 2) along transects and the stream reach were recorded on field data sheets for each Station ID.

For each transect, the following data were recorded:

- GPS Point ID
- Stream habitat type (riffle, run, pool, or other (specify))
- Canopy cover (open, partially shaded, and shaded)
- Left and right bank natural buffer width (m)
- Left and right bank riparian zone (upland forest, natural shrub dominated, floodplain forest, herbaceous marsh, managed shrub dominated corridor, regularly mowed corridor, planted urban landscape, pasture, row crops, denuded/eroded bank, concrete, rip rap, and other (specify))
- Upstream, downstream, left bank, and right bank photo numbers
- Steepest left and right bank slope (degrees)
- Stream width (m), reach length (m), and lowest terrace channel width (m)
- Stream depths (m) (0.25, 0.5, 0.75 distance along stream width)(thalweg)
- Left and right bank ease of access to the stream by way of the bank (easy, moderately easy, moderately difficult, and difficult)
- Stream conductivity, dissolved oxygen, and pH

In addition, air temperature, water temperature, salinity, and secchi depth were recorded at transect 1 (the transect furthest downstream).

For each stream reach the following were recorded:

- Dominant substrate (cobble, gravel, sand, silt, clay, natural organic matter, sludge, submerge logs or branches, bedrock, concrete, rip rap, and other (specify))
- Water odor (none, chemical, acrid, sewage, rotten egg, fishy, and musky)
- Water color (clear, light green, dark green, tan, tea color, red, green/brown, and black)
- Water surface (clear, scum, foam, debris, sheen, and oil)
- Aquatic vegetation (absent, rare, common, abundant, and over abundant)
- Algae cover (absent, rare, common, abundant, and over abundant)
- Stream type (ephemeral, intermittent, intermittent with perennial pools, and perennial)
- Stream flow (dry, no flow, low, normal, high, and flooded)

- Stream sinuosity (none, low, moderate, and high)
- Fish observed (categorical) (none, slight presence, moderate presence, large presence, game fish, and rough fish)
- Number of vertebrates (count of turtles, frogs, snakes, water dependent birds, alligators, wild mammals, domesticated mammals, and livestock)
- Visible large garbage in the channel within the reach (categorical) (0, 1-2, 3-10, and 11+)
- Visible small garbage in the channel within the reach (categorical) (0, 1-25, 26-75, and 76+)
- Visible bank garbage within 5m of the channel within the reach (categorical) (0, 1-25, 26-75, and 76+)
- Palmer Drought Index (categorical) (severe drought, moderate drought, mid range, moderately moist, very moist, and extremely moist)

Recreational Use and Site Assessment Methodology

To help determine the amount of recreation taking place on Houston streams, categorical information and photographs were collected to characterize the general conditions at each station, record evidence of human use, and provide information on key characteristics of each station (stream segment) that might encourage, or prevent humans from recreating at this location.

For each Station ID the following were recorded:

- General surroundings A (categorical) (urban, suburban, and rural)
- General surroundings B (categorical) (forested, grass/low vegetation, and pavement)
- General surroundings C (categorical) (agricultural/pastoral, residential, commercial, and industrial)
- Site conditions (categorical) (with photos) (none, park, playground, school, campground, sports field/park, beach, social trail, developed trail, road (paved/unpaved), stairs, paved parking lot, unimproved parking lot, dock/platform, commercial outfitter, boating access, golf course, private property, vandalism/graffiti, no trespassing sign, steep slopes, power line corridor, live

stock watering, cow manure/pasture, row crops, oil/chemicals, negative sounds/noise, and other)

- Indications of human use (with photos) (none, fishing tackle, children's toys, forts/tree houses, personal items, camping sites, fire pit/ring, bottles on the bank, rope swings, RV/ATV track, bullet casings, foot prints, patios with views, scenic views/overlooks, gates on the stream corridor, organized stream events, evidence of homeless, and other (specify))
- Cannel obstructions (with photos) (none, fences, barbed wire, low bridges, log jams, dams, culverts, rip rap, thick vegetation, water control structure, utility pipe, and other (specify))
- Channel modifications (with photos) (none, channelization, drainage ditches, concrete lining, rip rap, point sources, storm drains, NPDES (National Pollutant Discharge Elimination System), and other (specify))
- Accessibility of stream reach by walking (relatively inaccessible, moderately accessible, highly accessible, and unknown)
- Accessibility of stream reach by boating downstream from the nearest bridge (relatively inaccessible, moderately accessible, highly accessible, and unknown)
- Does the water body go within 1 mile of an area on the stream with major recreation activities or a bathing beach? (yes, no, and comments)

Site and Aerial Photographic Stream Channel and Corridor Assessment Methodology

Photographs were taken at each station for each sampling event. In addition, GIS based aerial photograpghs were obtained to provide landscape level site information. Using these information sources, a subjective categorical methodology was carried out to characterize the degree of anthropogenic disturbance from a pristine state for both the stream channel and corridor at each station. This, in turn, will provide a measure of aesthetic value of each survey station.

For each Station ID the following were classified:

- Stream channel appearance (categorical) (concrete, concrete/rip rap, ditch, rip rap, relatively unaltered/rip rap, and relatively unaltered)

- Corridor appearance (categorical) (concrete, commercial, mowed, natural/residential, and natural)
- Buffer size (categorical) (none, small, small/medium, medium, medium/large, and large)
- Park (actual name of the park encompassing the station)
- Landscape surroundings (industrial, commercial, residential/commercial, residential/park, golf course, residential/rural, residential/natural, rural, park/pasture, park, and natural)

Human Presence Methodology

A table was used to document the presence and activities of humans within the reach at each station over the course of the RUAA. Photographs were taken whenever possible.

For each Station ID the following were recorded:

- Person number (count)
- Group number each person was apart of (count)
- Approximate age of each individual (categorical) (<18, 19-24, 25-64, and 65+)
- Proximity to the water (categorical) (codes 1-6) (1-water in mouthy or nose, 2-body immersed in water (primary touch), 3-fishing, pets and related contact with water (secondary touch), 4-in a boat touching water, 5-body on shore within 8m (25 ft) of water, and 6-body well away from water between 8 and 30m (25-100 ft))
- Primary activity (categorical) (codes 1-19) (1-drinking or water in mouth, 2-swimming/bathing/diving (specify), 3-wading (children), 4-wading (adults), 5-canoeing/kayaking/rafting/tubing (specify), 6-fishing, 7-motor boating, 8-walking, 9-jogging/running, 10-bicycling, 11-motor cycle/ATV, 12-standing, 13-sitting, 14-lying down/sleeping, 15-playing on shoreline, 16-picnicking, 17-hunting/trapping (specify), 18-wildlife watching, and 19-other (specify))
- Total number of people recorded (count)
- Total number of groups recorded (count)
- Comments and photo numbers

RESULTS

Watershed characterization

I. Physical Evaluation

The non tidal portion of Buffalo Bayou/White Oak Bayou Stream System surveyed in this study includes 14 mostly perennial streams, ranging from 1.2 to 24.01 miles long (Table 1). In Buffalo Bayou and its tributaries, average thalweg was 1.23 m (ranging from 0.09 – 14.2) while in White Oak Bayou and its tributaries, average thalweg was 0.69 m (ranging from 0.02 – 2.10). Draught severity in the system, which was assessed by the Palmer Draught Index, was categorized as mid range throughout the survey period. Total discharge ranged from 0.1 ft^3/s in Magnum Canal to 155 ft^3/s in one station of South Mayde Creek sampled in June (Table 2).

A total of 14 recreational areas occur along the Buffalo Bayou/White Oak Bayou Stream System. The larger recreation areas, which are all located on Buffalo Bayou, include George Bush Park (Baker Reservoir), Addicks Reservoir, Bear Creek Park, Memorial Park, Terry Hershey Park, and Pine Forest Country Club.

Table 1. Description of surveyed streams in Buffalo Bayou/White Oak Bayou Stream System. Measurements were conducted during the summer of 2008. Stream type represents the dominant condition in the stream.

Stream	Segment #s	Length (miles)	# of Stations	# of Recreational. Areas on Stream	Avg. Thalweg (m)	Stream Type
BBC	20/24	22.68	12	4	1.43	perennial
BBU	24	19.97	12	2	0.71	perennial
BC	1076	16.79	10	1	0.41	perennial
BG	1057/1058/692	5.82	3	1	0.17	perennial/intermittent
CC	36	7.06	4	1	0.46	perennial
LC	1073	10.92	6	1	0.61	perennial/intermittent
MAG	N/A	1.2	1	1	0.41	perennial/intermittent
MC	1078/1079	6.98	4	1	0.57	perennial
NB	1063	3.19	2	0	0.67	perennial
RC	1067	3.02	2	1	0.42	perennial
SB	40	4.22	2	2	0.68	perennial
SMC	21/23	17.02	9	2	1.03	perennial
TC	41	5.79	3	1	0.16	perennial/ephemeral
UNK	1050	1.91	1	0	0.25	perennial/intermittent
WOB	19	24.01	14	3	0.60	perennial

Table 2. Stream Flow measurements in Buffalo Bayou/White Oak Bayou Stream System. Measurements were conducted during the summer of 2008 on eleven cross sections.

Stream	Station ID	Date	Stream Width (m)	Cross Section Width (ft) (W)	Total Discharge (Q) (ft^3/s)
BBC	BBC 5	8/3/2008	15	4.47	40
BC	BC46	8/10/2008	3.6	1.07	4.21
BG	BG77	7/13/2008	Too shallow		
CC	CC80	7/6/2008	9.25	2.76	2.42
LC	LC67	6/27/2008	5.42	1.62	7.95
LC	LC67	8/2/2008	3.47	1.03	6.40
UNK	UNK	8/9/2008	Too shallow		
MAG	MAG84	8/9/2008	5	1.49	0.10
MC	MC73	7/12/2008	8.72	2.60	9.60
MC	MC73	8/2/2008	6	1.79	2.93
NB	NB39	6/29/2008	5.5	1.64	0.32
NB	NB39	8/3/2008	6.7	2.00	0.21
RC	RC41	6/28/2008	6	1.79	0.69
RC	RC41	8/10/2008	4.9	1.46	0.96
SB	SB43	6/29/2008	7.25	2.16	1.93
SB	SB43	8/3/2008	8.27	2.47	3.67
SMC	SMC27	6/27/2008	8.4	2.51	155
SMC	SMC27	7/13/2008	9	2.68	15
SMC	SMC28	8/9/2008	13.5	4.03	31
TC	TC36	6/27/2008	8.1	2.42	1.05
TC	TC36	8/3/2008	5	1.49	1.19
WOB	WOB16	6/29/2008	3.6	1.07	30
WOB	WOB13	8/10/2008	12.5	3.73	44

II. Physicochemical Evaluation

In general, water characteristics were similar among the two bayous and their tributaries (Table 3). In Buffalo Bayou and its tributaries average DO (dissolve oxygen) was 5.72 mg/L (0.48 – 11.4), average pH was 7.94 (7.0 – 9.2), average conductivity was 554.1 µS (128 – 903), average salinity was 0.26 ppt (0.1 – 0.45), average transparency was 0.28 m (0.01 – 0.65), and average water temperature was 30.43°C (27.7 – 34.5) (these values were calculated based on the values reported in Table 3). In White Oak Bayou and its tributaries average DO (dissolve oxygen) was 9.39 mg/L (3.43 – 19.41), average pH was 8.49 (7.47 – 10.80), average conductivity was 714.82 µS (401 – 899), average salinity was 0.32 ppt (0.20 – 0.45), average transparency was 0.42 m (0.11 – 0.64), and average water temperature was 31.10°C (27.95 – 34.70).

Table 3. Maximum depth and mean of physicochemical water characteristics of Buffalo Bayou/White Oak Bayou Stream System. Values are presented from upstream to down stream and were calculated from measurements conducted during the summer of 2008, excluding obvious outliers. Abbreviations: VMD = Secchi disk was still visible at maximum depth.

Station ID	Max depth (m)	D.O. (mg/L)	pH	Conductivity (µS)	Salinity (ppt)	Secchi (m)	Water Temp (°C)
BBC 3	1.43	5.97	7.97	420.60	0.20	0.12	29.75
BBC 2	1.98	5.41	7.80	713.60	0.30	0.19	29.45
BBC 1	1.34	5.34	7.70	669.37	0.30	0.22	29.80
BBC 12	2.10	4.81	7.87	473.00	0.20	0.23	28.90
BBC 11	1.70	4.53	7.77	485.67	0.20	0.25	29.50
BBC 10	2.05	4.91	7.70	480.00	0.20	0.24	29.35
BBC 9	2.44	5.10	7.77	490.00	0.20	0.31	29.55
BBC 8	1.55	5.06	7.70	490.33	0.20	0.24	29.95
BBC 7	1.45	5.01	7.73	490.00	0.20	0.28	30.30
BBC 6	1.88	4.88	7.70	507.00	0.25	0.37	30.10
BBC 5	2.37	6.51	8.17	729.00	0.35	0.46	30.60
BBC 4	1.77	6.43	8.20	725.67	0.35	0.44	30.80
BBU 66	0.33	3.54	7.70	348.20	0.20	VMD	29.95
BBU 65	0.27	7.67	8.47	516.35	0.25	0.12	33.05
BBU 64	0.66	8.86	8.17	630.93	0.30	0.47	30.75
BBU 63	1.42	8.63	8.53	833.67	0.35	0.43	33.05
BBU 62	0.69	10.35	8.67	599.67	0.30	0.20	33.55
BBU 61	0.73	8.17	8.13	702.33	0.35	0.12	33.40
BBU 60	0.57	7.82	8.03	724.00	0.35	0.20	32.15
BBU 59	1.33	9.76	9.03	655.13	0.35	0.17	33.80
BBU 58	1.10	3.24	7.95	532.08	0.25	0.23	30.40
BBU 57	1.55	3.71	7.95	560.60	0.25	0.28	30.65
BBU 56	2.54	2.98	7.67	384.25	0.15	0.24	30.75
BBU 55	1.12	4.99	8.47	703.67	0.35	0.20	31.40
BC 54	0.31	5.58	8.40	653.35	0.30	0.05	28.20
BC 53	0.10	9.83	7.40	291.70	0.10	VMD	30.10
BC 52	0.09	11.40	7.00	255.10	0.10	VMD	29.00
BC 51	0.65	5.18	7.30	652.73	0.10	0.10	29.00
BC 50	0.52	8.66	7.83	821.00	0.40	VMD	32.25
BC 49	1.04	5.70	8.33	799.00	0.40	0.46	31.45
BC 48	0.87	1.42	7.72	584.25	0.30	0.24	30.55
BC 47	0.56	3.93	7.87	392.30	0.15	0.24	28.70
BC 46	0.42	4.76	7.23	583.5	0.35	0.40	30.90
BC 45	0.73	3.92	7.72	687.00	0.35	VMD	29.40
BG 79	0.42	3.43	7.53	777.33	0.40	0.32	28.75
BG 78	0.14	19.41	9.37	565.00	0.25	0.14	31.35
BG 77	0.05	13.59	10.80	495.50	0.20	VMD	33.10
CC 83	0.57	6.47	7.47	796.67	0.35	0.47	30.95
CC 82	0.64	4.04	8.20	673.33	0.35	0.17	28.85
CC 80	0.73	4.97	7.83	769.50	0.30	0.63	29.30

Table 3. Continued.

Station ID	Max depth (m)	D.O. (mg/L)	pH	Conductivity (µS)	Salinity (ppt)	Secchi (m)	Water Temp (°C)
LC 72	0.00	5.50	7.50	128.00	0.10	0.01	34.50
LC 71	0.50	3.32	7.37	165.70	0.10	0.20	28.53
LC 70	0.57	7.67	8.10	699.13	0.33	0.30	30.07
LC 69	1.66	7.49	8.07	903.00	0.45	0.65	31.95
LC 68	1.60	2.83	7.77	673.50	0.30	0.30	30.00
LC 67	1.10	3.27	8.00	666.43	0.30	0.39	30.20
Mag 84	0.45	8.23	8.20	414.37	0.20	0.11	31.55
MC 76	0.32	4.20	7.67	559.87	0.30	0.25	30.20
MC 75	1.90	6.80	8.10	623.67	0.30	0.63	32.10
MC 74	0.61	7.96	7.70	696.00	0.30	0.44	30.00
MC 73	0.65	10.46	8.70	646.70	0.30	VMD	33.40
NB 40	1.24	3.69	7.87	849.25	0.45	VMD	29.05
NB 39	0.73	5.65	8.23	453.47	0.25	0.51	29.95
RC 42	0.42	8.06	8.70	333.73	0.20	0.36	32.35
RC 41	0.85	4.47	7.43	419.27	0.20	VMD	28.30
SB 44	0.65	11.22	9.20	399.60	0.20	0.26	32.00
SB 43	1.25	8.09	8.17	683.33	0.30	0.52	29.25
SMC 29	0.24	3.46	7.70	232.27	0.15	0.05	29.05
SMC 30	0.21	4.07	7.73	192.47	0.10	0.03	29.20
SMC 31	0.39	7.18	8.20	789.67	0.40	0.20	32.35
SMC 32	1.42	3.03	7.80	848.67	0.40	0.39	31.50
SMC 33	0.65	3.75	7.70	619.50	0.20	0.25	30.40
SMC 34	0.64	2.67	7.70	563.67	0.30	0.23	27.85
SMC 35	0.88	3.37	7.87	526.67	0.25	VMD	28.25
SMC 28	3.33	4.82	7.67	469.47	0.25	0.46	29.30
SMC 27	14.20	6.31	7.93	511.83	0.25	0.24	29.05
TC 38	0.06	0.48	7.80	189.70	0.10	VMD	27.70
TC 37	0.25	3.99	7.90	352.78	0.15	0.13	29.95
TC 36	0.59	6.59	8.00	574.00	0.30	VMD	29.65
UNK 85	0.43	7.16	8.20	518.07	0.20	0.25	27.95
WOB 26	0.02	9.50	10.50	401.00	0.20	VMD	32.00
WOB 25	0.58	6.43	7.70	721.67	0.35	VMD	31.55
WOB 24	0.41	8.14	8.07	871.00	0.45	0.31	32.20
WOB 23	0.94	11.47	8.43	899.33	0.40	0.60	32.15
WOB 22	1.25	7.50	8.33	798.33	0.35	0.37	32.60
WOB 21	1.12	9.61	8.33	572.13	0.20	VMD	32.75
WOB 20	1.55	6.80	7.97	863.67	0.40	0.54	30.00
WOB 19	2.10	6.88	8.03	773.00	0.40	0.64	30.60
WOB 18	0.48	7.25	8.03	789.00	0.35	0.54	29.30
WOB 17	0.50	10.22	8.53	809.67	0.40	0.50	29.80
WOB 16	0.45	13.16	8.70	780.00	0.30	0.45	31.10
WOB 15	0.72	14.41	8.90	781.75	0.35	0.52	32.50
WOB 14	0.52	15.48	9.15	708.80	0.20	0.42	33.25
WOB 13	1.13	16.44	9.17	787.25	0.35	0.62	34.70

Station Description

A total of 85 stations were sampled between June 6 and August 10, 2008 (Figure 8 and 9). In addition to proximity to recreation areas (Table 5) and maximum depth (Table 3), street location, county location, general surroundings, riparian zone description, and point source information were collected for each station (Table 4).

Twenty seven of the sampled stations were located within parks and other recreational areas, mostly on Buffalo Bayou and its tributaries (23 total) (Table 1, Figures 6 and 7). Two stations on White Oak Bayou were located within T.C. Jester Park and one in White Oak Park. The stretch of the stream that goes through these parks, however, has been channelized with concrete lining on both banks. Moreover, two industrial outfalls discharge directly into the White Oak Bayou upstream of the sampling station (WOB 13) located in White Oak Park.

Most of the stations had relatively shallow depth. Thirty three stations had maximum depth over 1 m, 18 stations had maximum depth over 1.5 m, and only eight stations had maximum depth over 2 m.

Seventy seven stations were located in Harris County, seven in Fort Bend County, and one in Waller County.

Buffalo Bayou and its tributaries are generally located in suburban/residential areas with portions that are also located in natural, agricultural, pastoral, commercial and industrial areas. White Oak Bayou and its tributaries, are generally located in suburban/residential areas with some portions located in commercial and industrial areas.

The upper portion of Buffalo Bayou Unclassified (BBU 66 to 55) has riparian zones converted to regularly mowed corridors or managed shrub corridors. The middle and lower portions of Buffalo Bayou have forested riparian areas with either upland or flooded forests. All stations on White Oak Bayou and its tributaries except for one on Cole Creek (CC82) had riparian zones converted to regularly mowed corridor or covered by concrete lining.

Point source information includes the number of industrial outfalls, sewage outfalls ≥1 million of gallons per day (MGD), and sewage outfalls <1 MGD within the station's stream reach (first number) (Example: BBC 2 sewage outfalls ≥1 MGD **0**/1) and directly upstream of the stations stream reach (second number) (Example: BBC 2 sewage outfalls ≥1 MGD 0/**1**). On Buffalo Bayou and its tributaries there is one domestic and waste water treatment plant outfall ≥ 1 MGD within one of the stream reaches sampled. There are also two industrial outfalls, nine sewage ≥1 MGD, and 19 domestic waste water outfalls less than 1 MGD, directly upstream of sampled stream reaches. In White Oak Bayou and its tributaries there are two sewage outfalls ≥1 MGD within stream reaches sampled. There are also two industrial outfalls, three sewage outfalls ≥1 MGD, and five sewage outfalls <1 MGD directly upstream of sampled stream reaches (See Table 4 for station locations of these point sources).

Table 4. Location, general surroundings, and point sources present at 85 sampled stations in the Buffalo Bayou/White Oak Bayou Stream System.

Station ID	Street Location	County	General Surroundings	Riparian Zone	Industrial Outfall/ Upstream	Sewage ≥1 MGD/Up-stream	Sewage <1 MGD/Up -stream
BBC 1	Between N Kirkwood Rd and N Wilcrest Dr	Harris	residential	Floodplain Forest			
BBC 2	Between S Dairy Ashford Rd and S Eldridge Pkwy	Harris	agricultural/pastoral	Floodplain Forest		0/1	
BBC 3	Between N Eldridge Pkwy and State Highway 6	Harris	residential	Upland forest			
BBC 4	Between San Felipe St. and Memorial Dr	Harris	residential	Upland forest			
BBC 5	Between 610 and S Post Oak Ln	Harris	commercial	Upland forest			
BBC 6	Between Sage Rd. and Chimney Rock Rd	Harris	residential	Upland forest			
BBC 7	Between Chimney Rock Rd. and Voss Rd.	Harris	residential	Upland forest			
BBC 8	Between Chimney Rock Rd. and Voss Rd.	Harris	residential	Upland forest			
BBC 9	Between S. Voss Rd and Piney Point Rd.	Harris	residential	Upland forest		0/1	
BBC 10	Between S. Voss Rd and Piney Point Rd.	Harris	residential	Upland forest			
BBC 11	Between S. Gessner Dr. and W. Sam Houston Parkway S	Harris	residential	Upland forest			
BBC 12	Between S. Gessner Dr. and W. Sam Houston Parkway S	Harris	residential	Upland forest		0/1	
BBU 55	West of State Highway 6 within George Bush Park	Harris	industrial	Floodplain forest			
BBU 56	West of State Highway 6 within George Bush Park	Harris	agricultural/pastoral	Floodplain Forest			
BBU 57	West of Barker Clodine Rd within George Bush Park	Harris	agricultural/pastoral	Floodplain Forest			
BBU 58	North of Westheimer Pkwy within George Bush Park	Harris	agricultural/pastoral	Floodplain Forest			
BBU 59	Between Westheimer Pkwy and Mason Rd.	Ft. Bend	agricultural/pastoral	Regularly mowed corridor			
BBU 60	Between Westheimer Pkwy and Mason Rd.	Ft. Bend	residential	Regularly mowed corridor			
BBU 61	Between Mason Rd. and Peek Rd	Ft. Bend	residential	Regularly mowed corridor			
BBU 62	Between Green Bush Rd. and Cinco Ranch Blvd.	Ft. Bend	residential	Regularly mowed corridor			0/1
BBU 63	Between Green Bush Rd. and Katy Flewellen Rd.	Ft. Bend	residential	Regularly mowed corridor			0/3
BBU 64	Between Green Bush Rd. and Katy Flewellen Rd.	Ft. Bend	agricultural/pastoral	Regularly mowed corridor			
BBU 65	Between Katy Fwy and F.M. 1463	Ft. Bend	residential	Managed shrub dominated corridor			
BBU 66	Between U.S. Hwy 90 Bus and Bartlett Rd.	Waller	industrial	Managed shrub dominated corridor			
BC 45	Between Katy Fwy. and Patterson Rd.	Harris	agricultural/pastoral	Floodplain Forest			
BC 46	Betw. S.H. 6 and Eldridge Pkwy in Bear Creek Pioneer's Park	Harris	residential	Regularly mowed corridor			

Table 4. Continued.

Station ID	Street Location	County	General Surroundings	Riparian Zone	Industrial Outfall/ Upstream	Sewage ≥1 MGD/Up-stream	Sewage <1 MGD/Up-stream
BC 47	Betw. Groeschke Rd. & Clay Rd. in Congressman Archer Pk.	Harris	agricultural/pastoral	Floodplain Forest			
BC 48	Betw. Groeschke Rd. & Clay Rd. in Congressman Archer Pk.	Harris	residential	Herbaceous marsh			0/1
BC 49	Between Old Greenhouse Rd. and Clay Rd.	Harris	agricultural/pastoral	Regularly mowed corridor			0/2
BC 50	Between Fry Rd. and Greenhouse Rd.	Harris	residential	Regularly mowed corridor		0/1	
BC 51	Between Fry Rd. and Stockdick Rd.	Harris	residential	Regularly mowed corridor			
BC 52	Between Peek Rd. and Stockdick Rd.	Harris	agricultural/pastoral	Upland forest			0/1
BC 53	Between Porter Rd. and Peek Rd.	Harris	agricultural/pastoral	Upland forest			
BC 54	Between Katy Hockley Cut off Rd. and Stockdick School Rd.	Harris	agricultural/pastoral	Pasture			
BG 77	Between W. T.C. Jester Blvd. and Watonga	Harris	residential	Concrete			
BG 78	Between Kempwood Dr. and Hempstead Rd.	Harris	residential	Concrete			
BG 79	Between Tanner Rd. and Clay Rd.	Harris	commercial	Regularly mowed corridor			
CC 80	Between TC Jester Blvd. and Antoine Dr.	Harris	commercial	Regularly mowed corridor		1/0	
CC 81	Between Bingle Rd. and Hollister St.	Harris	residential	Regularly mowed corridor			
CC 82	Between Hempstead Hwy. and W. Little York Rd.	Harris	commercial	Natural shrub dominated corridor			0/1
CC 83	Between W. Sam Houston Parkway S and Brittmoore Rd.	Harris	commercial	Regularly mowed corridor			
LC 67	Between State Highway 6 andN. Eldridge Pkwy	Harris	agricultural/pastoral	Upland forest		0/1	0/1
LC 68	Between State Highway 6 andN. Eldridge Pkwy	Harris	commercial	Regularly mowed corridor		0/1	0/4
LC 69	Between Barker Cypress Rd. and Queenston Blvd.	Harris	residential	Regularly mowed corridor		0/1	
LC 70	Between Greenhouse Rd. and Barker Cypress Rd	Harris	residential	Regularly mowed corridor		0/1	
LC 71	Between Fry Rd. and Barker Cypress Rd.	Harris	residential	Upl.for./Natural shrub dom. corridor			
LC 72	Between Fry Rd. and Katy Hockley Rd.	Harris	agricultural/pastoral	Upl.for./Natural shrub dom. corridor			
MAG 84	Between Mangum Rd. and W TC Jester Blvd	Harris	residential	Regularly mowed corridor			
MC 73	North of Westheimer Pkwy within George Bush Park	Harris	residential	Upland forest			0/2
MC 74	Between S. Fry Rd. and Westgreen Blvd.	Harris	residential	Regularly mowed corridor			
MC 75	Between S. Mason Blvd and Westgreen Blvd.	Harris	residential	Regularly mowed corridor			
MC 76	Between Franz Rd. and Colonial Pkwy.	Harris	residential	Regularly mowed corridor		1/0	
NB 39	Between Sage Rd. and Chimney Rock Rd	Harris	residential	Upland forest			
NB 40	Between Antoine Dr. and Memorial Dr.	Harris	residential	Planted Urban landscape			

Table 4. Continued.

Station ID	Street Location	County	General Surroundings	Riparian Zone	Industrial Outfall/ Upstream	Sewage ≥1 MGD/Up-stream	Sewage <1 MGD/Up-stream
RC 41	Between W. Sam Houston Parkway S and Wilcrest Dr.	Harris	residential	Upland forest			
RC 42	Between W. Sam Houston Parkway S. and N. Wilcrest Dr.	Harris	residential	Regularly mowed corridor			
SB 43	Between Sage Rd. and Chimney Rock Rd	Harris	residential	Upland forest			
SB 44	Between Westview Dr. and Bingle Rd.	Harris	residential	Planted Urban landscp.corr./rip rap			
SMC 27	Between Briar Forest Dr. and Memorial Dr.	Harris	residential	Upland forest			
SMC 28	Between Katy Fwy and Patterson Rd.	Harris	residential	Floodplain Forest			
SMC 29	Between Peek Rd. and Porter Rd.	Harris	agricultural/pastoral	Floodplain Forest			0/1
SMC 30	Between Stockdick School Rd. and Clay Rd.	Harris	agricultural/pastoral	Floodplain Forest			
SMC 31	Between Morton Rd. and Clay Rd.	Harris	residential	Regularly mowed corridor			
SMC 32	Between Fry Rd. and N. Westgreen Blvd.	Harris	residential	Managed shrub dominated corridor			0/1
SMC 33	Between Greenhouse Rd. and Fry Rd.	Harris	residential	Regularly mowed corridor			0/2
SMC 34	Between State Highway 6 and Barker Cypress Rd.	Harris	agricultural/pastoral	Upland forest		0/1	
SMC 35	Between State Highway 6 and Barker Cypress Rd.	Harris	agricultural/pastoral	Upland forest			
TC 36	Between Enclave Pkwy and Memorial Dr.	Harris	residential	Uplnd. forest/Regularly mowed corr.			
TC 37	Between Old Katy Rd. and Clay Rd.	Harris	agricultural/pastoral	Floodplain Forest			
TC 38	Between N. Eldridge Pkwy. and Addicks Dam Rd.	Harris	agricultural/pastoral	Floodplain Forest			
UNK 85	Between E TC Jester Blvd. and N Durham Dr.	Harris	residential	Regularly mowed corridor			
WOB 13	Between Houston Ave. and Taylor St.	Harris	residential	Regularly mowed corridor/concrete	0/2		
WOB 14	Between Heights Blvd. and Studemont St.	Harris	residential	Regularly mowed corridor/concrete			
WOB 15	Between Durham Dr. and TC Jester Blvd	Harris	commercial	Regularly mowed corridor/concrete			0/1
WOB 16	Between W TC Jester Blvd. and E TC Jester Blvd	Harris	residential	Regularly mowed corridor/concrete			
WOB 17	Between W. T.C. Jester Blvd. and Watonga	Harris	residential	Regularly mowed corridor/concrete			
WOB 18	Between Pinemont Dr. and W. Tidwell Rd.	Harris	residential	Regularly mowed corridor/concrete			
WOB 19	Between Antoine Dr. and TC Jester Blvd.	Harris	residential	Regularly mowed corridor			
WOB 20	Between N Houston Rosslyn Rd. and Antoine Dr.	Harris	residential	Regularly mowed corridor		0/1	0/1

Table 4. Continued.

Station ID	Street Location	County	General Surroundings	Riparian Zone	Industrial Outfall/ Upstream	Sewage ≥1 MGD/Up-stream	Sewage <1 MGD/Up-stream
WOB 21	Between Fairbanks N. Houston Rd. and Hollister St.	Harris	residential	Regularly mowed corridor			0/2
WOB 22	Between W. Sam Houston Pkwy. S and Gessner Dr.	Harris	residential	Regularly mowed corridor		0/1	
WOB 23	Between Jones Rd. and W. Sam Houston Pkwy S	Harris	residential	Regularly mowed corridor		0/1	
WOB 24	Between Jones Rd. and W. Sam Houston Pkwy S	Harris	residential	Regularly mowed corridor			
WOB 25	Between Huffmeister Rd and N Eldridge Pkwy	Harris	residential	Regularly mowed corridor		1/0	
WOB 26	Between Hempstead Hwy. and Huffmeister Rd.	Harris	residential	Regularly mowed corridor			

Site and Aerial Photographic Stream Channel and Corridor Assessment

Site and aerial photographs were used to characterize the degree of anthropogenic disturbance from a pristine state of each sampling station based on the degree of alteration of the channel and corridor. Sampling stations that are characterized by a relatively unaltered stream channel, natural corridors, large buffer size, that are located within a park and are surrounded by a natural landscape; are considered closest to pristine conditions and to be the most valuable for recreation activities and nature experiences. Twelve sampling stations meet these requirements: BBU 55 to BBU 58, BC 45 and 47, MC 73, SMC 28, SMC 34 and 35, TC 37 and 38 all of which are located within Buffalo Bayou and its tributaries. In addition to these, the station BBC1 also meets the above criteria except for the fact that it is located adjacent to Lakeside Country Club which is a managed landscape. On the other end of the spectrum, were stations that are characterized by a concrete, concrete/rip rap or a ditch stream channel, a mowed, concrete or commercial corridor, with none or a small buffer zone, not adjacent or within a park, and surrounded by an industrial, residential/commercial or residential landscape. We found nine stations with those characteristics: BG 78, BG 79, SB 44, WOB 14 and 15, WOB 18, WOB 26, CC 83, and MAG 84. In addition, four other stations meet the above criteria but are located within parks that include walking/jogging trails. These stations are: BG77, WOB 13, and WOB 16 and 17.

The degree of anthropogenic alteration of stream channels varied among stations and streams. Fifty seven stations had relatively unaltered channels, 10 were categorized as

relatively unaltered channel/rip rap (BBC, CC, NB, and WOB), 11 were lined with concrete (WOB, BG, and TC), two were ditches (CC, and MAG), one had significant amounts of rip rap (UNK), and one had concrete/rip rap (SB).

Table 5. Stream channel and corridor assessment per sampled station in the Buffalo Bayou/White Oak Bayou Stream System.

Station ID	Stream Channel Appearance	Corridor Appearance	Buffer Size	Park	Landscape Surroundings
BBC 1	Relatively unaltered	Natural	Large	Lakeside Country Club	Park
BBC 2	Relatively unaltered	Natural	Small	Terry Hershey	Residential
BBC 3	Relatively unaltered	Natural	Small	Terry Hershey	Residential
BBC 4	Relatively unaltered/Rip rap	Natural	Large	Memorial Park	Park
BBC 5	Relatively unaltered	Natural	Small	Edge Memorial Park	Commercial
BBC 6	Relatively unaltered	Natural/Residential	Small	None	Residential
BBC 7	Relatively unaltered/Rip rap	Natural	Medium	Golf Course/Wooded	Residential/ Park
BBC 8	Relatively unaltered	Natural	Small	Golf Course/Wooded	Residential/ Commercial
BBC 9	Relatively unaltered/Rip rap	Natural/Residential	Small	None	Residential/ Commercial
BBC 10	Relatively unaltered/Rip rap	Natural/Residential	Small	None	Residential
BBC 11	Relatively unaltered/Rip rap	Natural	Small	None	Residential
BBC 12	Relatively unaltered/Rip rap	Natural/Residential	Small	None	Residential
BBU 55	Relatively unaltered	Natural	Large	George Bush Park	Natural
BBU 56	Relatively unaltered	Natural	Large	George Bush Park	Natural
BBU 57	Relatively unaltered	Natural	Large	George Bush Park	Natural
BBU 58	Relatively unaltered	Natural	Large	George Bush Park	Natural
BBU 59	Relatively unaltered	Mowed	None	None	Natural
BBU 60	Relatively unaltered	Mowed	Small	None	Natural
BBU 61	Relatively unaltered	Mowed	Small	None	Residential
BBU 62	Relatively unaltered	Mowed	None	None	Residential
BBU 63	Relatively unaltered	Mowed	None	None	Natural
BBU 64	Relatively unaltered	Mowed	None	None	Pasture
BBU 65	Relatively unaltered	Mowed	None	None	Residential
BBU 66	Relatively unaltered	Mowed	None	None	Industrial
BC 45	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural

Table 5. Continued.

Station ID	Stream Channel Appearance	Corridor Appearance	Buffer Size	Park	Landscape Surroundings
BC 46	Relatively unaltered	Mowed	None	Golf Course/Bear Creek Pioneers Park	Golf Course
BC 47	Relatively unaltered	Natural	Large	Congressman Bill Archer Park	Natural
BC 48	Relatively unaltered	Mowed	None	Congressman Bill Archer Park	Residential
BC 49	Relatively unaltered	Mowed	None	None	Golf Course
BC 50	Relatively unaltered	Mowed	None	None	Residential/Natural
BC 51	Relatively unaltered	Mowed	None	None	Residential
BC 52	Relatively unaltered	Natural	Medium	None	Rural
BC 53	Relatively unaltered	Natural	Medium	None	Rural
BC 54	Relatively unaltered	Natural	Small	None	Rural
BG 77	Concrete	Mowed	None	TC Jester	Residential
BG 78	Concrete	Concrete	None	None	Residential
BG 79	Concrete	Mowed	None	None	Residential
CC 80	Relatively unaltered/Rip rap	Mowed	None	None	Residential
CC 81	Relatively unaltered	Mowed	None	None	Residential
CC 82	Relatively unaltered/Rip rap	Natural	Small	None	Commercial
CC 83	Ditch	Mowed	None	None	Industrial
LC 67	Relatively unaltered	Natural	Large	None	Natural
LC 68	Relatively unaltered	Mowed	None	None	Commercial
LC 69	Relatively unaltered	Mowed	None	None	Residential
LC 70	Relatively unaltered	Mowed	None	None	Residential
LC 71	Relatively unaltered	Natural	Medium	None	Rural
LC 72	Relatively unaltered	Natural	Medium	None	Residential/Rural
MAG 84	Ditch	Mowed	None	None	Industrial
MC 73	Relatively unaltered	Natural	Large	George Bush Park	Natural
MC 74	Relatively unaltered	Mowed	None	None	Residential
MC 75	Relatively unaltered	Mowed	None	None	Residential/ Commercial
MC 76	Relatively unaltered	Mowed	None	None	Residential
NB 39	Relatively unaltered/Rip rap	Natural/Residential	Small	None	Residential
NB 40	Relatively unaltered	Natural/Residential	Small	None	Residential
RC 41	Relatively unaltered	Natural/Residential	Small	Terry Hershey	Residential
RC 42	Relatively unaltered	Natural	Small	None	Residential
SB 43	Relatively unaltered	Natural	Medium/Small	None	Residential
SB 44	Concrete/Rip rap	Commercial	Small	None	Residential/ Commercial
SMC 27	Relatively unaltered	Natural	Small	Terry Hershey	Residential
SMC 28	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural
SMC 29	Relatively unaltered	Natural	Small	None	Rural
SMC 30	Relatively unaltered	Natural	Medium/Large	None	Rural

Table 5. Continued.

Station ID	Stream Channel Appearance	Corridor Appearance	Buffer Size	Park	Landscape Surroundings
SMC 31	Relatively unaltered	Mowed	None	None	Residential
SMC 32	Relatively unaltered	Mowed	None	None	Residential
SMC 33	Relatively unaltered	Mowed	None	None	Residential
SMC 34	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural
SMC 35	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural
TC 36	Concrete	Natural/Residential	Small	None	Residential
TC 37	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural
TC 38	Relatively unaltered	Natural	Large	Addicks Reservoir	Natural
UNK 85	Rip rap	Commercial	None	None	Commercial
WOB 13	Concrete	Mowed	None	White Oak Park	Commercial
WOB 14	Concrete	Mowed	None	None	Residential/ Commercial
WOB 15	Concrete	Mowed	None	None	Residential
WOB 16	Concrete	Mowed	None	T.C. Jester Park	Residential
WOB 17	Concrete	Mowed	None	T.C. Jester Park	Residential
WOB 18	Concrete	Mowed	None	None	Industrial
WOB 19	Relatively unaltered	Mowed	None	None	Industrial
WOB 20	Relatively unaltered	Mowed	None	None	Residential
WOB 21	Relatively unaltered	Mowed	None	None	Residential
WOB 22	Relatively unaltered	Mowed	None	None	Industrial
WOB 23	Relatively unaltered	Mowed	None	None	Residential
WOB 24	Relatively unaltered/Rip rap	Mowed	None	None	Residential
WOB 25	Relatively unaltered	Mowed	None	None	Residential
WOB 26	Concrete	Mowed	None	None	Residential

Recreational Use of Houston Streams

A total of 249 people were observed in the Buffalo Bayou/White Oak Bayou Stream System during the surveys. Out of this, 21% were under 18 y, 17% were in the range of 19 to 24 y, 59% were in the rage of 25 to 64 y, 1.2 were over 65 y, and 1.6% were of unknown age. The most commonly observed activities were bicycling (32.5 %) walking (30.5 %), jogging/running 9.6 %, fishing (9.2 %), and motorcycle/ATV riding (7.2 %). There were more than five other types of recreational activities observed with each accounting for less than 5% of the total (Table 6).

In addition to the systematic records of human presence and activities described in the methodology, we adopted a behavior trace research approach to observe the recreation behaviors on eight selected sites along Buffalo Bayou (Appendix 1).

Table 6. Human activity registered in Buffalo Bayou/White Oak Bayou Stream System during the summer of 2008.

Station ID	Total	Fishing	Walking	Jogging/ Running	Bicycling	Motorcycle/ ATV	Standing	Sitting	Lying down/sleeping	Picnicking	Wildlife Watching	Other
BBC 1	7			2	5							
BBC 2	11		2		9							
BBC 3	5		1		4							
BBC 4	2										2	
BBC 5	1						1					
BBC 6	1						1					
BBC 7	1		1									
BBC 8	0											
BBC 9	0											
BBC 10	1			1								
BBC 11	0											
BBC 12	10			5	5							
BBU 55	28	4	19		4				1			
BBU 56	2	2										
BBU 57	14	5			9							
BBU 58	0											
BBU 59	11	9					2					
BBU 60	2				2							
BBU 61	10		2	4	3		1					
BBU 62	11		3	2	6							
BBU 63	0											
BBU 64	0											
BBU 65	0											
BBU 66	1											1
BC 45	0											
BC 46	6											6
BC 47	0											
BC 48	0											

Table 6. Continued.

Station ID	Total	Fishing	Walking	Jogging/ Running	Bicycling	Motorcycle/ ATV	Standing	Sitting	Lying down/sleeping	Picnicking	Wildlife Watching	Other
BC 49	4					4						
BC 50	0											
BC 51	0											
BC 52	0											
BC 53	0											
BC 54	0											
BG 77	4		4									
BG 78	0											
BG 79	0											
BG 80	1											1
BG 81	1											1
BG 82	0											
BG 83	0											
LC 67	0											
LC 68	0											
LC 69	3		2		1							
LC 70	0											
LC 71	0											
LC 72	0											
Mag 84	0											
MC 73	0											
MC 74	2		2									
MC 75	0											
MC 76	0											
NB 39	0											
NB 40	0											
RC 41	0											
RC 42	1		1									
RC 43	0											
SB 44	2				1			1				

Table 6. Continued.

Station ID	Total	Fishing	Walking	Jogging/ Running	Bicycling	Motorcycle/ ATV	Standing	Sitting	Lying down/sleeping	Picnicking	Wildlife Watching	Other
SMC 27	27	3	13	5	6							
SMC 28	0											
SMC 29	0											
SMC 30	0											
SMC 31	0											
SMC 32	3					3						
SMC 33	2											2
SMC 34	0											
SMC 35	0											
SMC 36	9		4		5							
SMC 37	0											
SMC 38	0											
Unk 85	1											1
WOB 13	16		8	1	6							1
WOB 14	0											
WOB 15	0											
WOB 16	2		1		1							
WOB 17	20		2	1	12					5		
WOB 18	2		2									
WOB 19	2		2									
WOB 20	1								1			
WOB 21	2					2						
WOB 22	0											
WOB 23	3					3						
WOB 24	5					5						
WOB 25	12		7	3	2							
Total	249	23	76	24	81	17	5	1	2	5	2	13

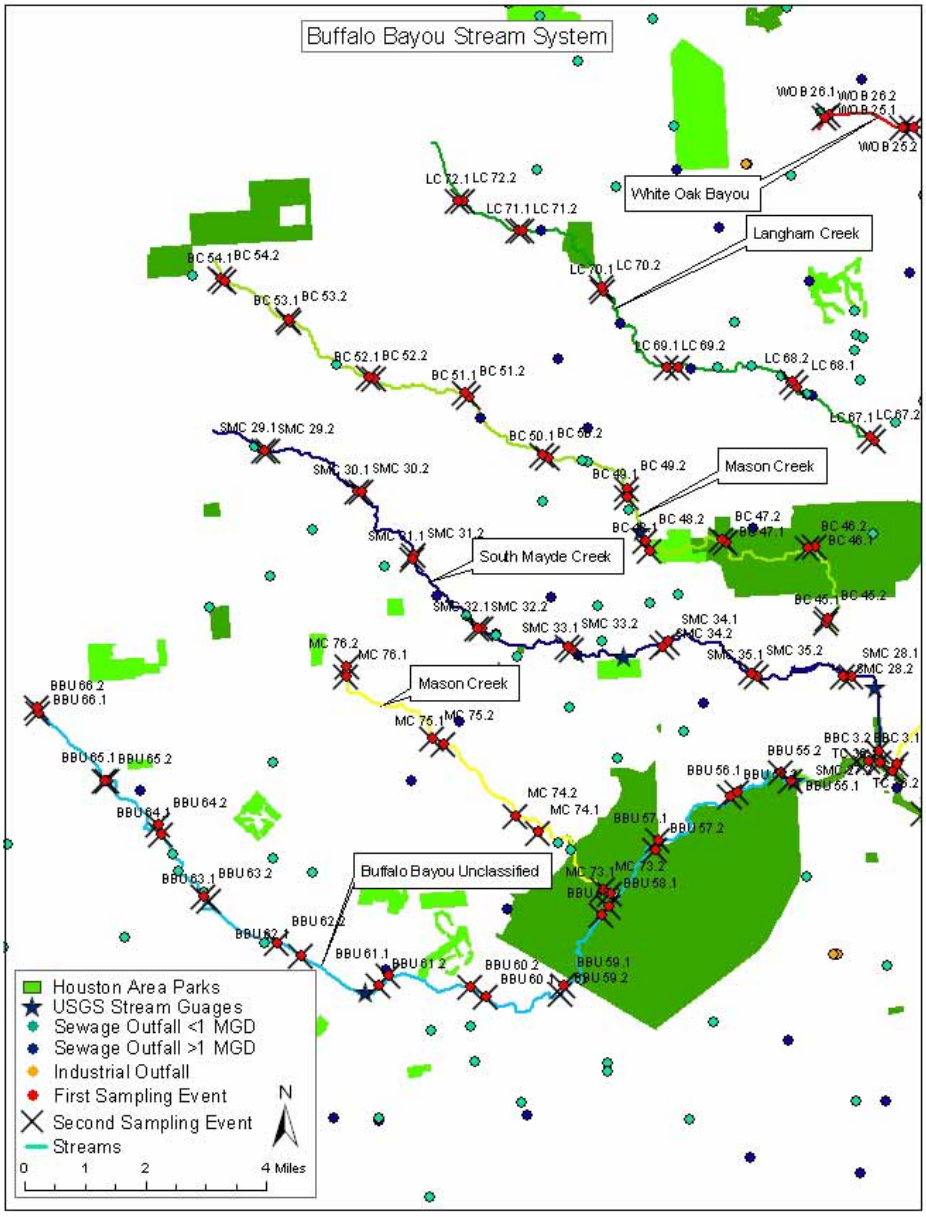

Figure 6. *GIS Characterization of Buffalo Bayou and its tributaries.*

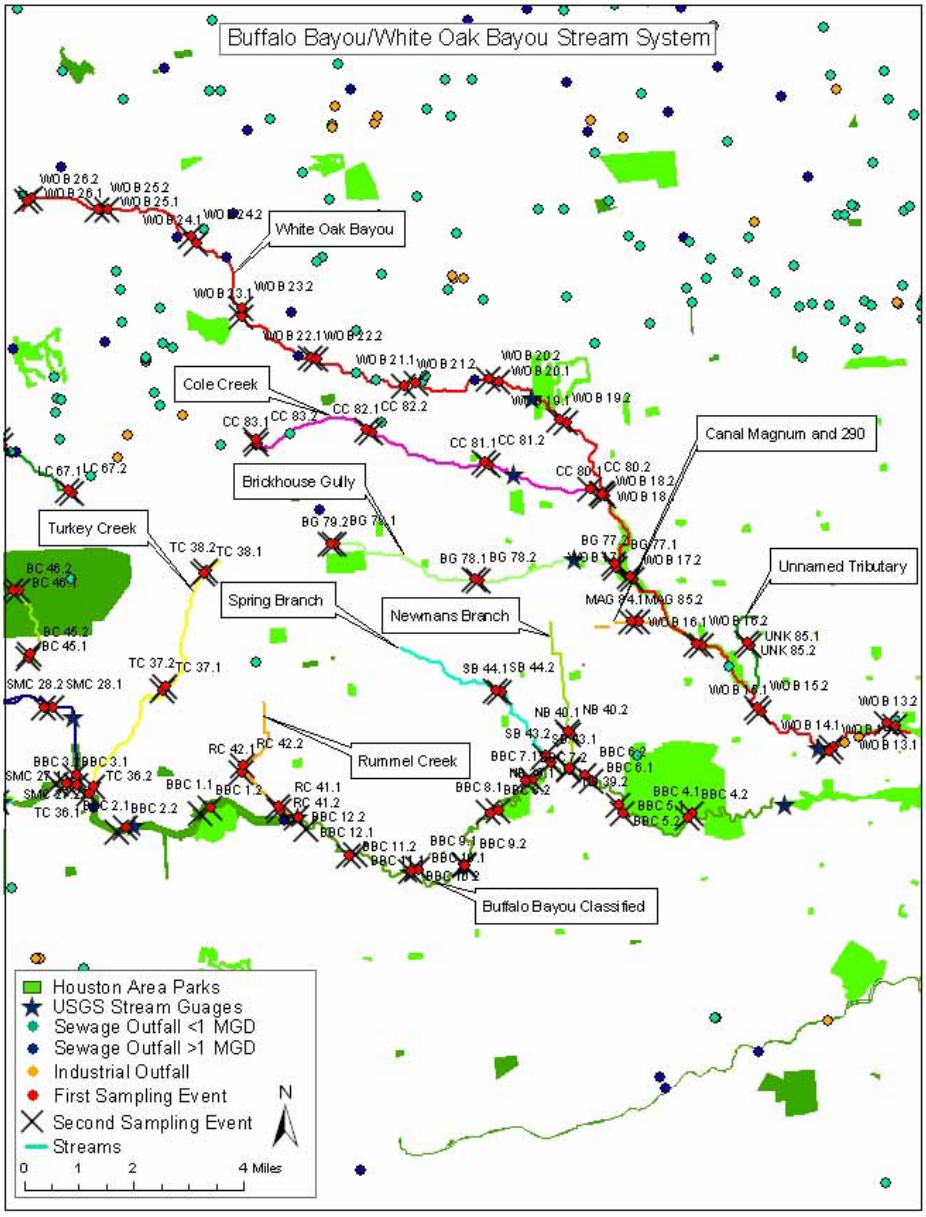

Figure 7. *GIS Characterization of White Oak Bayou and its tributaries.*

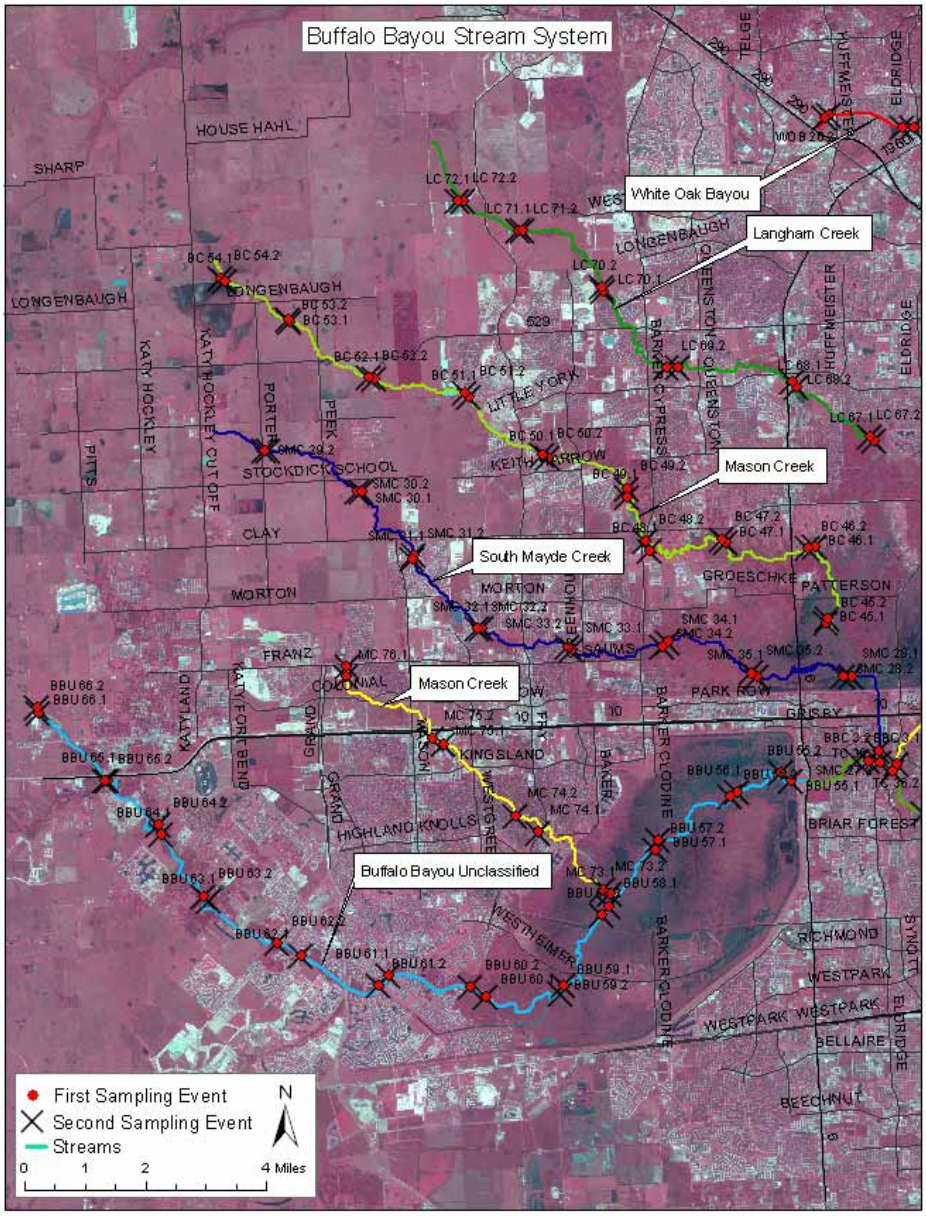

Figure 8. *Location of sampling stations along Buffalo Bayou and its tributaries.*

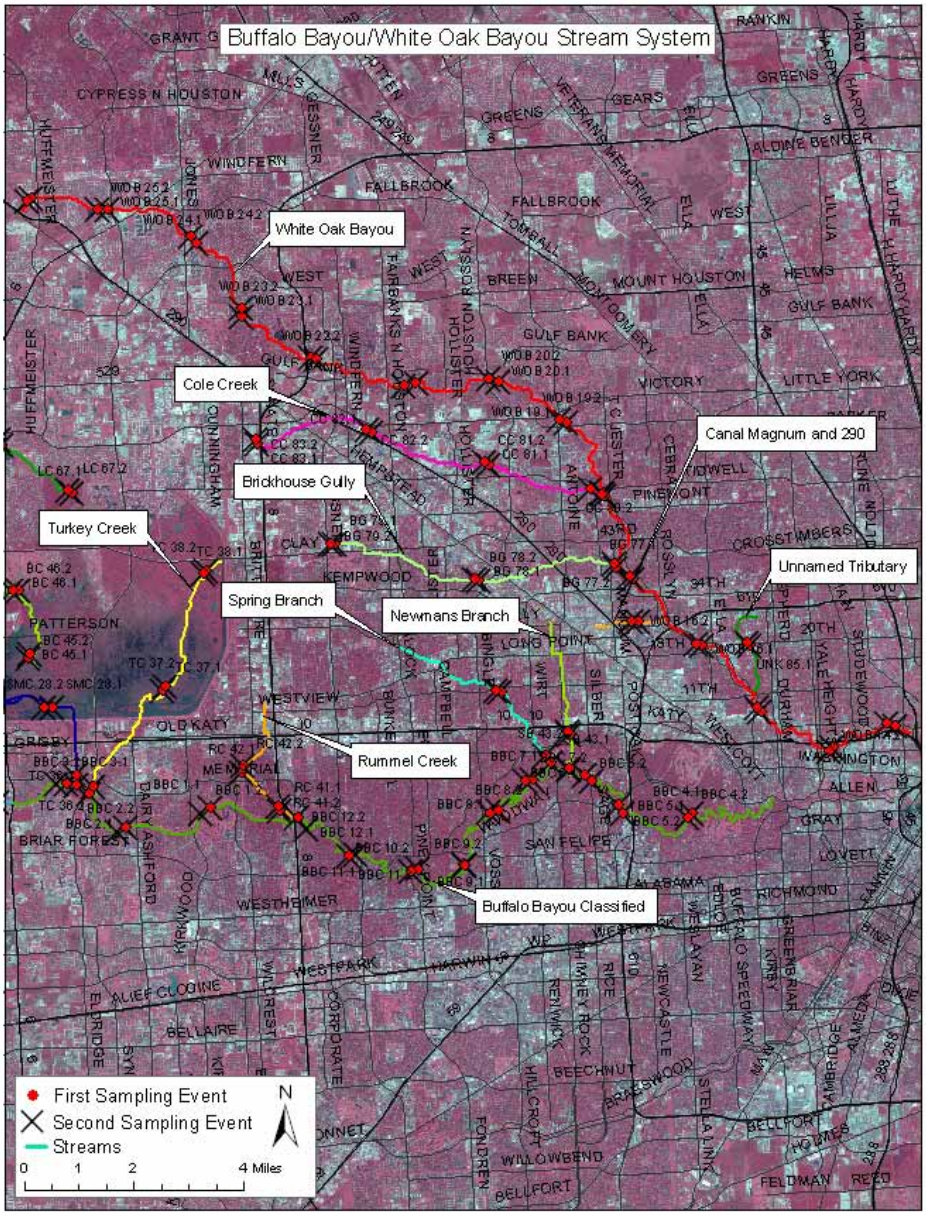

Figure 9. *Location of sampling stations along White Oak Bayou and its tributaries.*

SUMMARY

Eight five sites over 151 miles of the Buffalo Bayou/White Oak Bayou Stream System were surveyed in this RUAA to evaluate whether the existing and/or attainable recreational uses of the streams in this system might be different than the presumed recreational uses. Important factors examined in this RUUA included 1) environmental quality of streams, 2) potential sources of anthropogenic pollution, 3) water depth, 4) hydrological modifications and physical characteristics, and 5) current recreational uses. The following summarizes the information in the RUAA which was collected between June 6 and August 10, 2008.

1) Naturally occurring pollutant concentrations were not measured during this RUAA. Dissolved oxygen, pH, conductivity, salinity, transparency, and water temperature, however, were measured to assess the environmental quality of the streams. Based on the physicochemical evaluation of the Houston streams, averaged measurements indicated that relatively normal conditions existed in these waters. In Buffalo Bayou and its tributaries, average DO (dissolve oxygen) was 5.72 mg/L (0.48 – 11.4), average pH was 7.94 (7.0 – 9.2), average conductivity was 554.1 µS (128 – 903), average salinity was 0.26 ppt (0.1 – 0.45), average transparency was 0.28 m (0.01 – 0.65), and average water temperature was 30.43°C (27.7 – 34.5). In White Oak Bayou and its tributaries, average DO (dissolve oxygen) was 9.39 mg/L (3.43 – 19.41), average pH was 8.49 (7.47 – 10.80), average conductivity was 714.82 µS (401 – 899), average salinity was 0.32 ppt (0.20 – 0.45), average transparency was 0.42 m (0.11 – 0.64), and average water temperature was 31.10°C (27.95 – 34.70).

2) In addition to storm drains, multiple industrial and sewage outfalls were present within or directly upstream of the sampled reaches in the Buffalo Bayou/White Oak Bayou Stream System. These outfalls are sources of pollution that are a potential treat for humans coming in contact with the water, either directly or indirectly through activities such as wading and fishing. On Buffalo Bayou and its tributaries there is one domestic and waste water treatment plant outfall ≥ 1 MGD within one of the stream reaches sampled. There are also two industrial outfalls, nine sewage ≥1 MGD, and 19 domestic waste water outfalls less than 1 MGD, directly upstream of sampled stream reaches. In White Oak Bayou and its tributaries there are two sewage outfalls ≥1 MGD within stream reaches sampled. There are also two industrial outfalls, three sewage outfalls ≥1 MGD,

and five sewage outfalls <1 MGD directly upstream of sampled stream reaches (See Table 4 for station locations of these point sources).

3) Thirty three stations had maximum depth over 1 m, 18 stations had maximum depth over 1.5 m, and eight stations had maximum depth over 2 m.

4) Stream channels within the project consisted of natural, channelized, and concrete-lined segments. In general, the degree of alteration of stream channels was directly related to the amount and intensity of development around each segment. Based on the Site and Aerial Photographic Stream Channel and Corridor Assessment, 57 stations had relatively unaltered channels, 10 were categorized as relatively unaltered channel/rip rap (BBC, CC, NB, and WOB), 11 were lined with concrete (WOB, BG, and TC), two were ditches (CC, and MAG), one had significant amounts of rip rap (UNK), and one consisted of concrete/rip rap (SB).

5) A total of 14 recreational areas occur on streams within the system. The larger ones are George Bush Park (Baker Reservoir), Addicks Reservoir, Bear Creek Park, Memorial Park, Terry Hershey Park, and Pine Forest Country Club all of which are on Buffalo Bayou. Twenty seven of the sampled stations were located within parks and other recreational areas, mostly on Buffalo Bayou and its tributaries.

A total of 249 people were observed in the Buffalo Bayou/White Oak Bayou Stream System during 170 surveys of 85 stations. The most commonly observed activities were bicycling (32.5 %) and walking (30.5 %). Fishing, which was the activity involving the closest contact with water within sampled reaches, accounted for 9.2 % of these observations, with 23 individuals observed fishing at stations BBU 55, 56, 57, 59, and SMC 27 (Table 6). Outside of the boundaries of sampled reaches, no swimming was observed. Wading (5 people), cast netting (1 person), canoeing and kayaking (8 people), fishing (20-30 people), and rope swings adjacent to the water, however, were observed between June 6 and August 10, 2008. Throughout the summer, recreation involving primary water contact appeared to generally be concentrated along Buffalo Bayou particularly within George Bush Park and dams on the downstream end of both Barker Reservoir and Addicks Reservoir.

BBU 55, 56, 57, and 59, seemed to be among the least impacted or altered stream sites in the Houston area. BBU 55, 56, 57, 59 are all within George Bush Park or the Barker Reservoir. Based on Site and Aerial Photographic Stream Channel and Corridor Assessment results, BBU 55, 56, and 57 are all high quality, characterized by relatively unaltered stream channel, natural corridors, and large buffer size. These sites are located within a park and are surrounded by a natural landscape. SMC 27, which is in a residential area with a relatively small buffer width, is located just downstream from Addicks Reservoir within Terry Hershey Park and therefore could be considered high quality also. Based on the fact that 23 individuals were observed fishing at stations BBU 55, 56, 57, 59, and SMC 27, overall, there appears to be a positive relationship between environmental quality and the level of recreational use.

RECOMMENDATIONS

In the course of conducting the RUAA of the Buffalo Bayou/White Oak Bayou Stream System during the summer of 2008, much progress was made in develping a methodology that is information rich, efficient, and precise. During the survey of the first 85 sites, incremental changes in several procedures (ie. # of transects, measurement of bank slope, depths along the transects, etc.) helped to create this methodology. When comparing the data from the first and second survey events of the 85 stations, it is important to take this into account.

In conducting this fieldwork, a large amount of experience and knowledge was acquired. Based on experience gained from this project, the methods and data analyses of the RUAA program should be further evaluated, and when deemed appropiate, revised.

Current recommendations for future work are:

- Use TDS Recons to collect GPS points and record field data.
- Standardize survey time at each station.
- Standardize reach length across all stations irrespective of channel width.
- Start field sampling in the cooler spring months (April) when more recreation is likely to take place; complete sampling by early July.
- Conduct sampling along streams weighting effort within major recreational areas using a stratified random sampling design.
- Remove GIS/Internet related questions from fieldsheets since these are determined from non-field sources.

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Appendix 1
On-Site Observations of Recreation Uses along Buffalo Bayou

Purpose

The purpose was to supplement the information collected from different sources and provide a more comprehensive understanding of the influences of Buffalo Bayou on different types of recreation uses.

Methods

Eight areas along the Buffalo Bayou water bodies were sampled, including Barker Reservoir/George Bush Park, Addicks Dam/Bear Creek Park/Cullen Park, Terry Hershey Park, Memorial Park, Buffalo Bayou Park, Allen's Landing, and several sites adjacent to residential areas (See Figure 1 for the locations of the survey sites). Two survey teams were formed to sample these sites between 6:30 to 10:00 in the morning of August 2 and August 3, 2008, and 5:00 to 8:00 in the evening of August 1 and August 2, 2008. Each survey team surveyed one of the eight sites during every survey period and recorded/estimated the number of recreationists, activities they participated, their socio-demographic backgrounds, and their interactions with the water and other natural amenities supported by Buffalo Bayou.

Results

Tables 1 and 2 summarize the recreational uses supported by the parks along Buffalo Bayou and White Oak Bayou at the present time.

Although segments of Buffalo Bayou has been declared to be unsuitable for contact recreation, sporadic activities that involve body contact and secondary contact with the water of Buffalo Bayou were observed at Barker Reservoir, Allen's Landing, and Buffalo Bayou Park (Photo 1 & Photo 2).

Photo 1. Kids playing in the water

Photo 2. Fishing

Meanwhile, the Bayou and the riparian ecosystem it supports help maintain the habit for birds and lush canopy along portions of the Bayou. The dense trees at the bank of the Bayou not only provide shelter for birds and other wildlife (Photo 3). They also offer a few remaining natural environments in this highly urbanized area. Hiking and biking trails have been built along the Bayou allowing residents of the nearby residential areas to take the advantage of the shade and natural amenities supported by the Bayou. An hour observation at a segment of the hiking trail at the west end of Terry Hershey Park on a Saturday morning recorded approximately 200 recreationists taking part in activities, such as walking, jogging, biking, and dog-walking (Photo 4). Channelized portions of the Bayou running through residential areas despite of their modified environments and lack of natural shade were still used by individuals from the neighborhood for walking and running (Photo 5). During a two-hour period on a Sunday morning approximately 55 individuals were recorded using the trails along the channelized Bayou on Mason Road, primarily for jogging, biking, and walking. during a two-hour period on a Sunday morning.

Photo 3. Buffalo Bayou provides habitats for birds and other wildlife

Photo 4. Hiking and biking trail at Terry Hershey Park

Photo 5. Trail along a channelized section of Buffalo Bayou

Parks built along the Bayou also provide a venue for social and family gathering. Our observation at Barker Reservoir/George Bush Park indicated individuals of different ages and ethnicity not only used the green space created around the Bayou for the activities of biking, jogging, walking, dog-walking, and rollerblading. We also observed single families recreated in the green space with their children as well as multiple families who gathered to watch their kids practicing soccer (Photo 6 & Photo 7).

Photo 6. Family gathering

Photo 7. Parents watching teenagers exercising

Recreation and associated benefits seem to play an important part in Houstonians' life. Sustaining the function of Buffalo Bayou to support continuing recreation for most of the Houston residents may be critical in maintaining the quality of life in this urban setting. However, future research will be needed to examine this social aspect of the human-nature interactions.

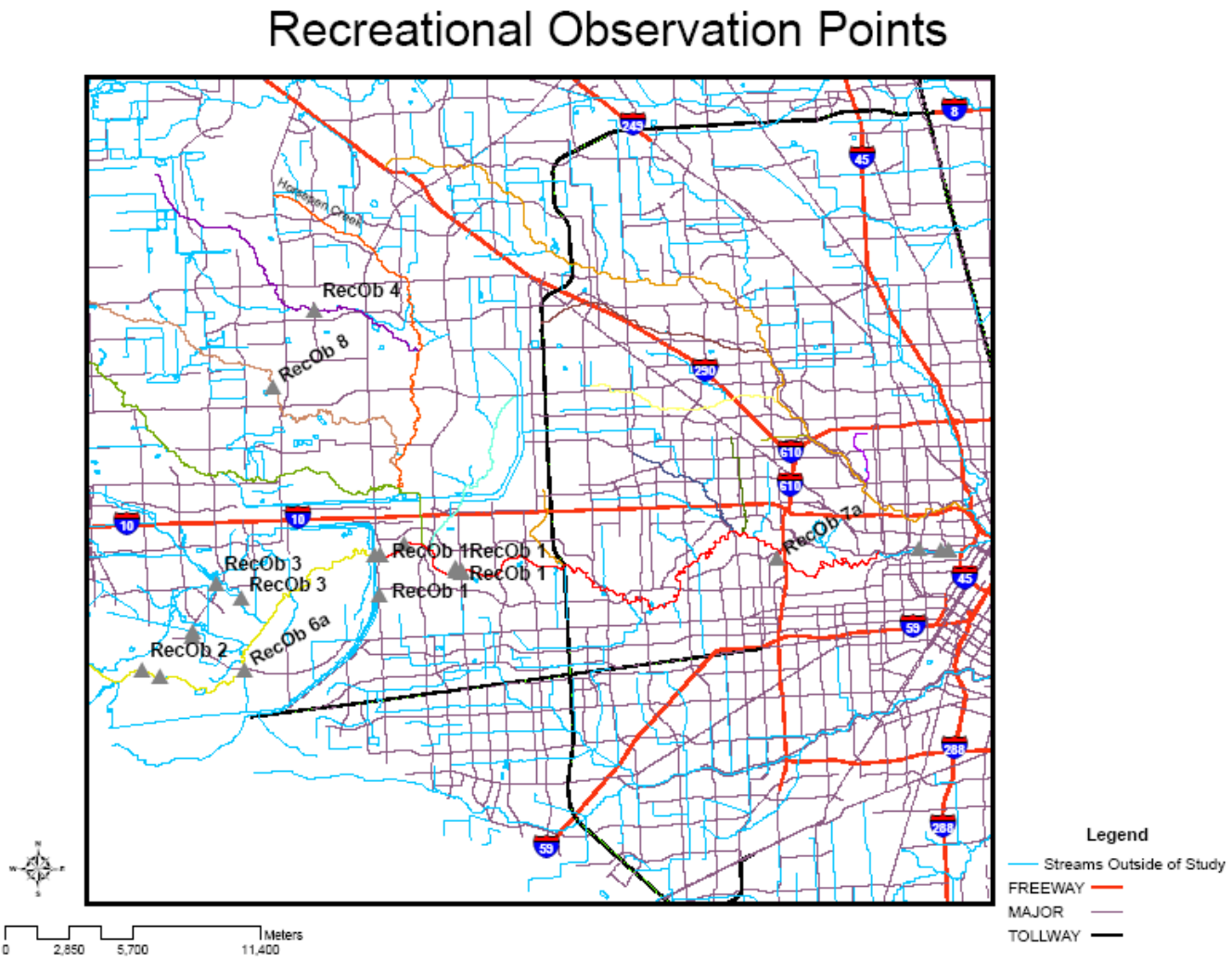

Figure 1. Locations of the selected survey sites for assessing current recreational use in Buffalo Bayou.

Table 1. Current parks and recreational uses along Buffalo Bayou.

Park/Facilities	Picnic Area	Hike/Bike Trail	Parking	Canoe Launch	Playground	Fishing	Bird Trail/Birding	Sport Field	Other Features
Barker Reservoir/George Bush Park	X	X	X	X	X	X	X	baseball, softball, soccer	Exercise station, nature trail, equestrian trail, shooting range, model airplane facility, YMCA
Addicks Dam/Bear Creek Park/Cullen Park	X	X	X	X	X	X	X	soccer, football, baseball, softball, basketball	Camping, nature trail, equestrian trail, golf course, exercise station, zoo, community center, velodrome, archery range
Terry Hershey Park		X	X						dog park
Weiss Park		X							
Memorial Park	X	X	X				X	Soccer, softball, baseball, tennis	Golf course, swim center, Houston Arboretum and Nature Center, equestrian trail, Memorial Park Fitness Center, and a multi-use trail for use by road bikers, in-line skaters, traditional roller skate enthusiasts, and hikers during regular park hours and automobile traffic from Monday through Friday from 11 a.m. to 1 p.m. and weekends and holidays.
Hogg Bird Sanctuary Park							X		
Cleveland Park		X	X						
Buffalo Bayou Park		X		X	X				Exercise station, golf course, dog walk, Buffalo Bayou Artpark, Fonde Recreation Center, Benches, Trash Receptacles and Drinking Fountains
Sabine-to-Bagby Promenade		X	X	X					Dramatic lighting, outstanding civic art, convenient street-to-bayou access, Buffalo Bayou Pedestrian Bridge, advanced channel edge construction, lush landscaping, wheelchair accessibility
Spotts Park	X	X			X				Benches, Trash Receptacles and Drinking Fountains

Table 1. Continued.

Sam Houston Park		X							Small pond with fountain, gardens, gazebo, Heritage Society homes, Heritage Society Museum, gift shop and offices, Houston Armillary Sphere Sculpture, USS Houston Memorial Sculpture, benches, trash receptacles and drinking fountains
Sesquicentennial Park	X	X	X	X					Space for outdoor events (The Common), Allen H. Carruth Promenade, Preston Avenue Bridge, The Garden Club of Houston Garden, George Bush Monument, The Josephine B. and Anthony Charles Muller Overlook, Seven Wonders
Allen's Landing	X	X	X	X					Concrete paved wharf designed to replicate the original Port, promenade, terrace overlooking bayou, entry plaza at intersection of commerce and main, terraced grass lawn, text-based public artwork, benches, trash receptacles, drinking fountain, bike rack, decorative lighting
James Bute Park									
Guadalupe Plaza Park		X	X						Performing arts area centered around a colonial zocalo, fountain, boat landing
Tony Marron Park	X	X	X		X			Soccer, baseball	Passive recreation area, benches, picnic tables, trash receptacles, drinking fountains
Hidalgo Park		X	X		X			Baseball	Quiosco (gazebo with concrete columns and railings to look like tree trunks), benches, trash receptacles, decorative lighting
Hartman Park									Community center gymnasiums, community center weight rooms

Table 2. Current parks and recreational uses along White Oak Bayou.

Park/Facilities	Picnic Area	Hike/Bike Trail	Parking	Canoe Launch	Playground	Fishing	Bird Trail/Birding	Sport Field	Other features
Woodland Park	X	X	X						Community center gymnasiums
White Oak Parkway		X	X						
Norman Way Park		X							
Stude Park		X	X						
West 11th St Park		X					X		An educational butterfly garden; native wild flowers and wildlife habitat
Timbergrove Manor Park		X							
Little Thicket Park	X	X	X				X		Wildlife habitat, research on the turtle populations in the park
Stonecrest Parkway		X	X						
Jester (T.C.) Parkway		X	X						
Watonga Parkway		X							

APPENDIX 2
Environmental Assessment Methodology Supplement

Dominant Substrate Type
The dominant channel substrate(s), which is the mineral or organic material that forms and/or collects on the bottom of the stream, was characterized for each stream reach by visually examining the substrate within 1m on either side of each transect. The substrate categories of cobble, gravel, sand, silt, clay, natural organic matter, sludge, submerge logs or branches, bedrock, concrete, rip rap and other (specify), were used to characterized the existing substrate. Cobble was characterized has having a diameter of 6-15 cm, gravel 2-60 mm, sand 0.06-2 mm, silt 0.002-0.06 mm, and clay < 0.002 mm.

Emergent Vegetation
Aquatic macrophytes (plants) that are rooted in the sediment, near shore or in marshes, with nearly all of the leaves above the water surface (cattails).

Floating Vegetation
Rooted plants (some free floating) with leaves floating on the surface (for example, water lily, water shield, duck weed, and water hyacinths).

Flow Measurement Method
Flow was measured with a Marsh-McBirney model flow meter. In addition, monthly flow measurements taken from USGS gauging stations were recorded. Flow values were recorded in cubic feet per second (ft3/s). Flow measurements were not recorded for dry streams or streams with not enougth water to cover the sensor on the flow meter.

Intermittent Stream
A stream that has a period of zero flow for at least one week during most years. Where flow records are available, a stream with a 7Q2 flow of less than 0.1 cfs is considered intermittent. The critical lowflow (7Q2) is the lowest flow that occurs for seven consecutive days during a two year period as statistically determined from historical data.

Intermittent Stream with Perennial Pools
Streams that may have periods of zero flow or a 7Q2 flow of less than 0.1 cfs, but maintain pools that create significant aquatic life uses.

Natural Vegetative Buffer
The natural vegetative buffer refers to an area of either natural or native vegetation that buffers the water body from terrestrial runoff and the activities of man. In natural areas, it may be much greater than the riparian zone width. In man-altered settings, the natural vegetative buffer limit would be at the point of man's influence in the riparian zone, such as a road, parking lot, pasture, or crop field. It is the width of this buffer that the TCEQ is most interested in measuring for purposes of qualifying potential stream disturbances.

Palmer Drought Index
This is the monthly value (index) that is generated indicating the severity of a wet or dry spell. This index is based on the principles of a balance between moisture supply and demand. Man-made changes were not considered in this calculation. The index generally ranges from -6 to +6, with negative values denoting dry spells and positive values indicating wet spells. There

are a few values in the magnitude of +7 or -7. PDSI values 0 to -.5 = normal; -0.5 to -1.0 = incipient drought; -1.0 to -2.0 = mild drought; -2.0 to -3.0 = moderate drought; -3.0 to -4.0 = severe drought; and greater than -4.0 = extreme drought. Similar adjectives are attached to positive values of wet spells. This is a meteorological drought index used to assess the severity of dry or wet spells of weather.

Perennial Stream
A stream that does not have a period of zero flow for greater than one week or where the 7Q2 flow is greater than 0.1 cfs.

Reach Length Determinations and Transect Placement
The reach length of the stream was calculated by multiplying the stream width (wetted width) by 40. Calculated values below 150m were assigned the value of 150m. Values above 300m were assigned the value 300 m. Two transects were placed perpendicular to the stream channel at the beginning and end of the reach which was found with the use of a range finder. Sampling began with the transect furthest downstream (transect number 1).

Riparian Zone
The riparian zone can be defined in many ways, but generally includes the area of the stream bank and out onto the flood plain. The limit of the zone depends on many factors including plant community, soil moisture, and distance from the stream. The riparian zone is periodically inundated by the flood waters from the stream.

Secchi Disk Transparency
Secchi disk data was measured to access the degree of eutrophication and suspended sediments at each location. These measurements were taken directly in the streams by use of waders or canoes. The disk was lowered in the water until it disappeared from view. After which, the disk was raised until visible. This process was repeated until an accurate depth at which the disk disappeared from view could be determined. This measurement was recorded. In shallow streams where the secchi disk was still visible on the bottom of the stream, this depth was recorded.

Steepest Bank Slope
Measure the slope of each bank at the transect with a clinometer and a survey rod or pole. Place one end of the survey rod at the base of the steepest part of the bank over 1 meter in length and lay the rod against this steep bank. Lay the clinometer on top of the survey rod and record the angle reading. Measure both left and right banks and record these angles separately.

Stream Depths at Points Across the Transect
Stream depth is the vertical height of the water column from the existing water surface level to the channel bottom. Measure the water depth in meters at 11 equally spaced points across each transect.

Stream Flow
Flow values can be highly dependent on the specific stream being measured. In this RUAA, six flow value categories included dry, no flow, low, normal, high, and flooded. A dry value characterized streams at sampling stations that were completely dry with no visible pools. A flow value of no flow describes situations where the stream has water

visible with no obvious surface flow. When a slight amount of water movement was detected, a value of low flow was recorded. When stream flow is considered normal, the value of normal was recorded. High flow values were recorded in situations where unusually high or fast moving water was observed. Flooded streams were defined as those streams that leave the confines of the normal stream channel and move out on to the flood plain.

Stream Habitat Type
Stream habitat type was recorded in the area where the each transect fell. Habitat categories included riffle, run, pool, and other (specify). The definitions of these are:
Pool. A portion of a stream where water velocity is slow and the depth is greater than the riffle, run, or glide. Pools often contain eddies with varying directions of flow compared to riffles, runs, and glides where flow is nearly exclusively downstream. The water surface gradient of pools is very close to zero and their channel profile is usually concave.
Riffle. A shallow portion of a stream extending across a stream bed characterized by relatively fast moving turbulent water with a broken water surface. The water column in a riffle is usually constricted and water velocity is fast due to a change in surface gradient. The channel profile in a riffle is usually straight to convex.
Run. A relatively shallow portion of a stream characterized by relatively fast moving, bank-tobank, non-turbulent flow. A run is usually too deep to be considered a riffle, but the water velocity is too fast to be a glide. The channel profile under a run is usually a uniform flat plane.

Stream Sinuosity
Count the number of stream bends and determine their definition (none, low, moderate, and high. A highly sinuous stream will usually have a point bar at the inside of the bend and a cut bank on the outside of the bend with flow directed toward the cut bank side. Eddy currents are usually found in these bends. Moderately sinuous streams have somewhat less sinuosity and the bends and point bars are not as well developed. Streams of low sinuosity have very little sinuosity or are close to being straight similar to a channelized stream.

Stream Width
Stream width is the horizontal distance along the transect line from water's edge to water's edge along the existing water surface. It is also referred to as the wetted width. Measure the width of the water in the stream channel from water's edge to water's edge at a transect. Water's edge can be defined as the point where stream materials, such as rocks, are no longer surrounded by water. It is important to remember that stream width is only the wetted width.

Thalweg
The deepest portion of the stream channel.

Transect Line
A straight line, perpendicular to stream flow, between two points on opposite stream banks.

Recreational Use Assessment Methodology

Ag/pastoral
A majority of land adjacent to the sample reach is undeveloped open space

Commercial
A majority of land adjacent to the sample reach is retail (shopping centers, restaurants)

Developed Trail
Appears to have been intentionally constructed for recreation/transportation use

Forested
A majority of the land adjacent to the sample reach is forested with trees.

Grass/low vegetation
A majority of land adjacent to the sample reach is vegetated with grass, weeds or a low shrub thicket (e.g., yaupon)

Homeless Residents
Evidence of homeless individuals or groups living in close proximity to the stream channel.

Industrial
A majority of land adjacent to the sample reach is factory, warehouse or manufacturing plant

Large Garbage or Trash
Examples are tires, shopping carts, appliances.

Litter
Examples are plastic shopping bags, bottles, cans, wrappers, milk cartons, paper scraps.

Negative sounds/noise
This might be heavy traffic, manufacturing, pumps or other “background” sounds that are undesirable.

No trespass sign
This may also be checked for signage that indicates “stay out” “no entry” of other message that prohibits access.

Oil or chemicals
Evidence of an oil slick or chemicals that discolor water or soil in the channel.

Park Any public or private park which may contain: athletic facilities, picnic areas, trails, nature center, recreation center

Pavement
A majority of land adjacent to the sample reach is impervious pavement (e.g. a parking lot)

Residential
A majority of land adjacent to the sample reach is houses and/or apartments

Rural
Low density development primarily open space and agriculture land use may include sparse residential and commercial, low traffic volumes

Social Trail
Appears to have been developed by local users for convenient access the water or edge of channel

Steep slopes
Banks are too steep to negotiate and make access to the water difficult.

Suburban
Less dense development primarily residential may include some commercial, few multiple story buildings, moderate traffic volumes

Urban
Dense commercial and residential development, characterized by multiple story buildings, high traffic volumes, etc.

Water control structure A structure built in or along the channel that inhibits access to or along the water.